Mahidol University *Wisdom of the Land*

Chapter 9

Template Matching

Template Matching

Target image $I(x, y)$ → **Output Image** $I(x', y')$

Target image

Template

Output image and found rectangle

Template Matching

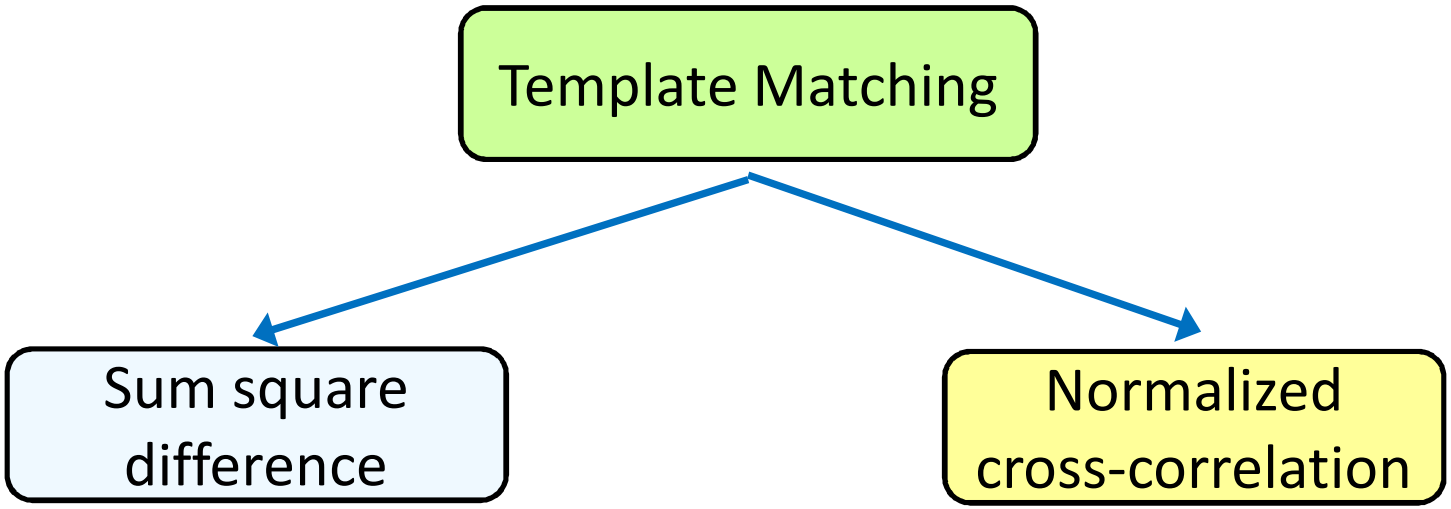
- Template matching is a simple method for object detection.
- Sample image should be used to recognize similar objects in original image.
- The goal of the template matching process is to find the positions on an target image which are best correlated with the template image.

Target image

Template

Output image and found rectangle

Template Matching



Sum Square Difference

- Sum square difference is one of the simplest of the similarity measures, which is calculated by difference between the template image and the sub-image of target image, as follows :

moving sub-image

$$g(x,y) = \sum_{s,t} [T(s,t) - f(x+s, y+t)]^2$$

- where : $T(s,t)$ is the template image

  $f(x,y)$ is the target image

  $g(x,y)$ is the sum of the differences squared

Example: Sum Square Difference

- This example is template matching for binary image.
- We want to find the object in the target image with the template image.

0	1	0	1	1
1	1	0	0	1
0	1	0	1	0
1	1	0	1	0
1	0	1	0	1

Target image

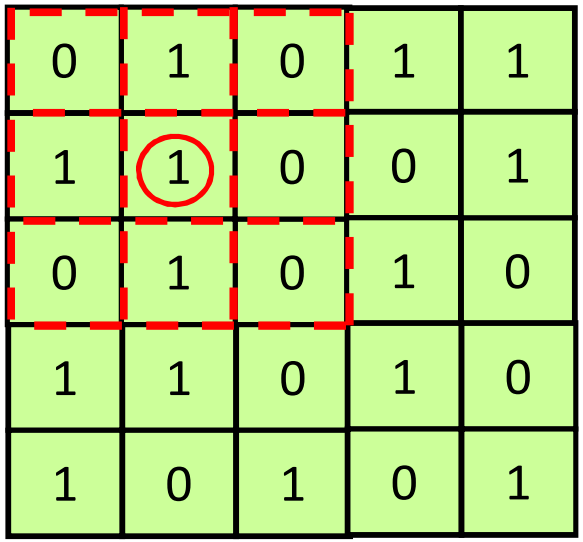
1	1	0
0	1	0
1	1	0

Template

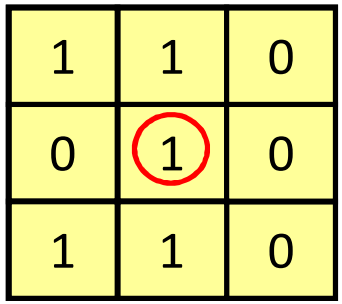
Example: Sum Square Difference

Position 1 : evaluate $g(x,y)=\sum_{s,t}(T(s,t)-f(x+s,y+t))^2$

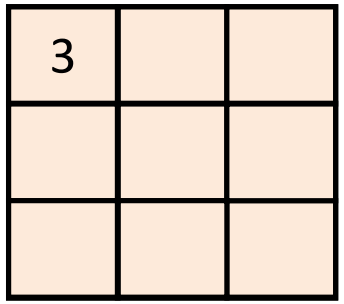
$$g_{1,1}=(1-0)^2+(1-1)^2+(0-0)^2+(0-1)^2+(1-1)^2+(0-0)^2+(1-0)^2+(1-1)^2+(0-0)^2=3$$



$f(x,y)$



$T(x,y)$



$g(x,y)$

Example: Sum Square Difference

Position 2 : evaluate $g(x,y)=\sum_{s,t}(T(s,t)-f(x+s,y+t))^2$

$$g_{1,2}=(1-1)^2+(1-0)^2+(0-1)^2+(0-1)^2+(1-0)^2+(0-0)^2+(1-1)^2+(1-0)^2+(0-1)^2=6$$

0	1	0	1	1
1	1	0	0	1
0	1	0	1	0
1	1	0	1	0
1	0	1	0	1

$f(x,y)$

1	1	0
0	1	0
1	1	0

$T(x,y)$

3	6	

$g(x,y)$

Example: Sum Square Difference

Position 3 : evaluate $g(x,y) = \sum_{s,t} (T(s,t) - f(x+s, y+t))^2$

$$g_{1,3} = (1-0)^2 + (1-1)^2 + (0-1)^2 + (0-0)^2 + (1-0)^2 + (0-1)^2 + (1-0)^2 + (1-1)^2 + (0-0)^2 = 5$$

0	1	0	1	1
1	1	0	0	1
0	1	0	1	0
1	1	0	1	0
1	0	1	0	1

$f(x,y)$

1	1	0
0	1	0
1	1	0

$T(x,y)$

3	6	5

$g(x,y)$

Example: Sum Square Difference

Position 4 : evaluate $g(x,y)=\sum_{s,t}(T(s,t)-f(x+s,y+t))^2$

$$g_{2,1}=(1-1)^2+(1-1)^2+(0-0)^2+(0-0)^2+(1-1)^2+(0-0)^2+(1-1)^2+(1-1)^2+(0-0)^2=0$$

0	1	0	1	1
1	1	0	0	1
0	1	0	1	0
1	1	0	1	0
1	0	1	0	1

$f(x,y)$

1	1	0
0	1	0
1	1	0

$T(x,y)$

3	6	5
0		

$g(x,y)$

Example: Sum Square Difference

Position 5 : evaluate $g(x,y)=\sum_{s,t}(T(s,t)-f(x+s,y+t))^2$

$$g_{2,2}=(1-1)^2+(1-0)^2+(0-0)^2+(0-1)^2+(1-0)^2+(0-1)^2+(1-1)^2+(1-0)^2+(0-1)^2=6$$

0	1	0	1	1
1	1	0	0	1
0	1	0	1	0
1	1	0	1	0
1	0	1	0	1

$f(x,y)$

1	1	0
0	1	0
1	1	0

$T(x,y)$

3	6	5
0	6	

$g(x,y)$

Example: Sum Square Difference

Position 9 : evaluate $g(x,y)=\sum_{s,t}(T(s,t)-f(x+s,y+t))^2$

$$g_{3,3}=(1-0)^2+(1-1)^2+(0-0)^2+(0-0)^2+(1-1)^2+(0-0)^2+(1-1)^2+(1-0)^2+(0-1)^2=3$$

0	1	0	1	1
1	1	0	0	1
0	1	0	1	0
1	1	0	1	0
1	0	1	0	1

$f(x,y)$

1	1	0
0	1	0
1	1	0

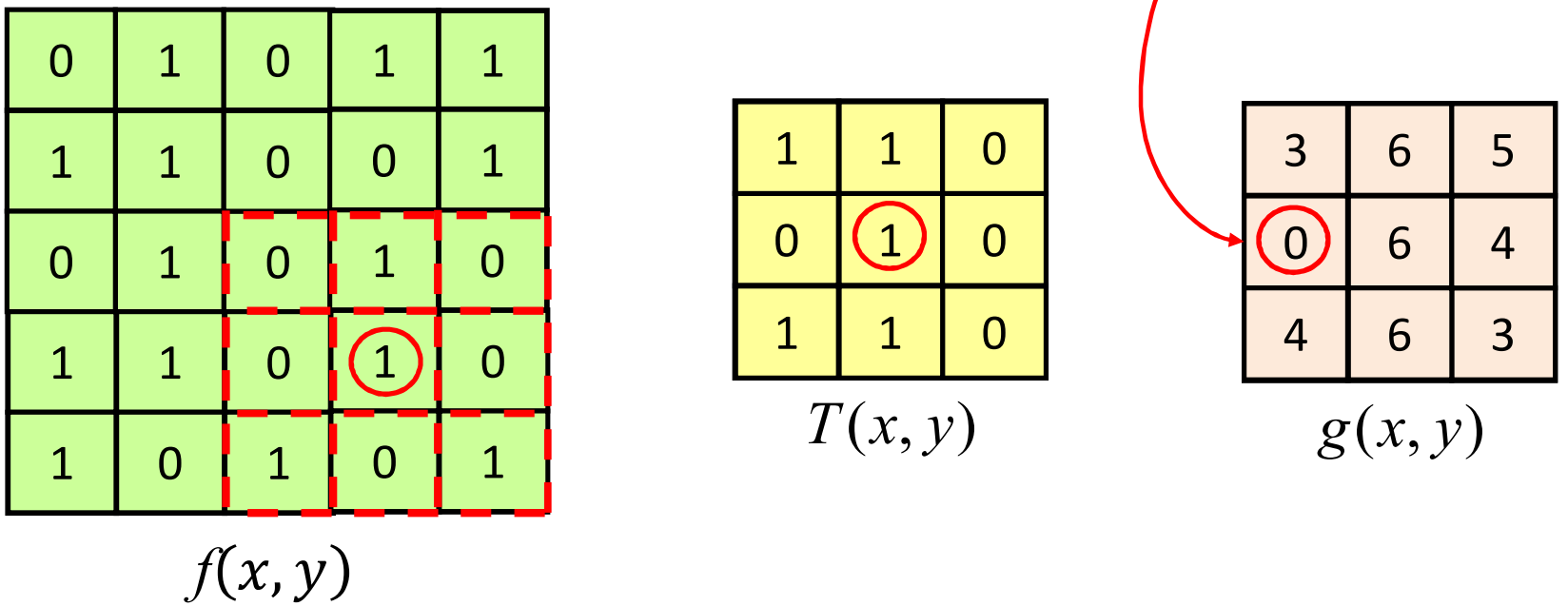
$T(x,y)$

3	6	5
0	6	4
4	6	3

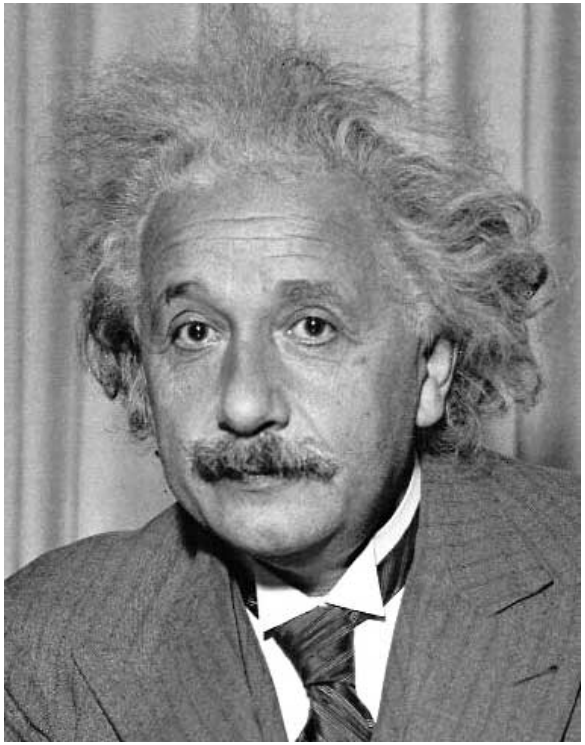
$g(x,y)$

Example: Sum Square Difference

- As all possible positions of the template image with respect to the search image are considered, the position with the minimum value is the best position.

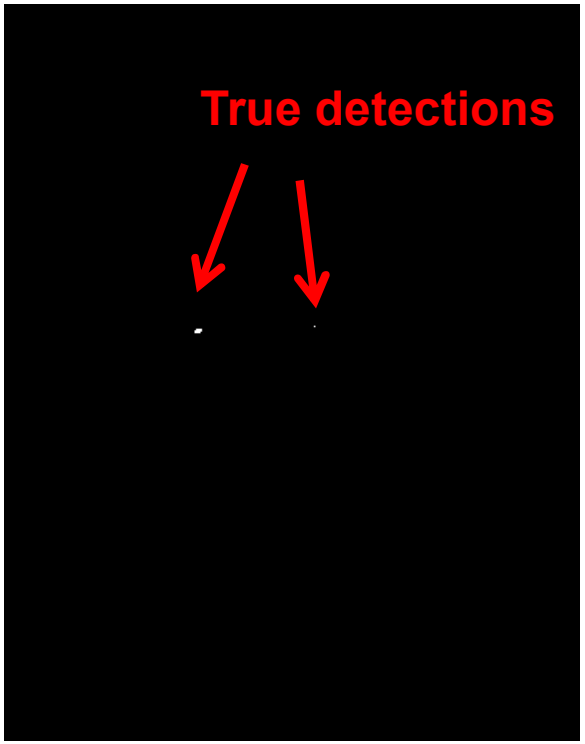


Example: Sum Square Difference



a) Target Image

b) Template



c) Matching result of (a) and (b)

Normalized cross-correlation

- Normalized cross-correlation is given by :

moving sub-image

$$g(x,y)=\frac{\sum_{s,t}\left[(T(x,y)-\bar{T}(x,y)).(f(x+s,y+t)-\bar{f}(s,t))\right]}{\left[\sum_{s,t}\left[f(x+s,y+t)-\bar{f}(s,t)\right]^2.\sum_{s,t}\left[f(x+s,y+t)-\bar{f}(s,t)\right]^2\right]^{\frac{1}{2}}}$$

- where :

$T(x,y)$ is the template image

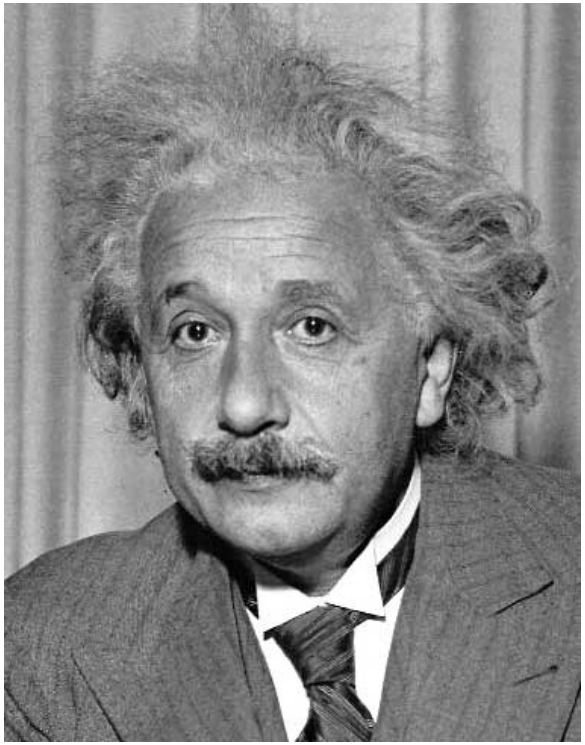
$\bar{T}(x,y)$ is the mean of template image

$f(s,t)$ is the sub-image of target image

$\bar{f}(s,t)$ is the mean of sub-image

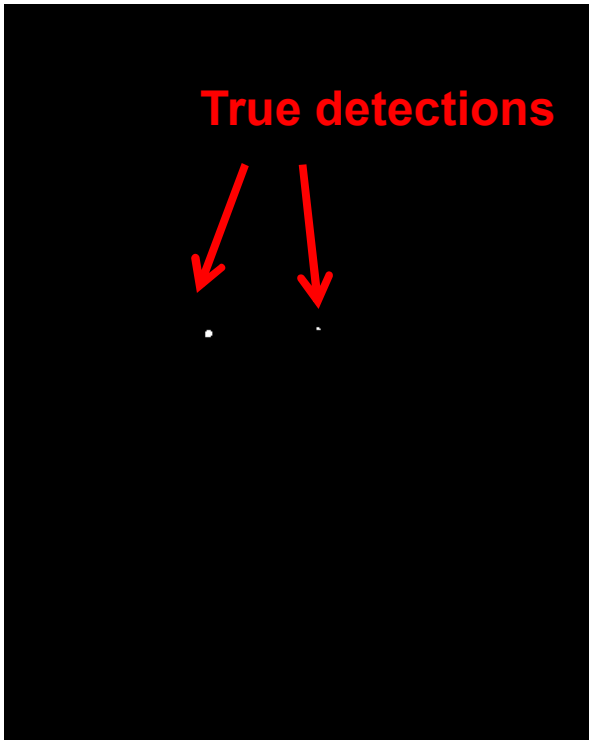
$g(x,y)$ is the correlation value. It ranges from -1.0 to +1.0

Example: Normalized cross-correlation



a) Target Image

b) Template



c) Matching result of (a) and (b)

What is the best method to use?

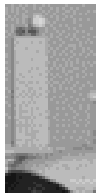
- Sum square difference:
  - Faster
  - Sensitive to overall intensity.
- Normalized cross-correlation:
  - Slower than the sum square difference
  - Invariant to local average intensity and contrast.

Limitations of Template Matching

- Sensitivity to changes in size and rotation
- Sensitivity to pattern distortion
- Heavy computational load

Example: Normalized cross-correlation

a) Target Image



b) Template

c) Matching result of (a) and (b)

Example: Normalized cross-correlation

a) Target Image

b) Template

c) Matching result of (a) and (b)

Thanks for your attention